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across different studies has shown that bib size consistently indicates male age and male fighting ability. Replicated studies of house sparrows provide us with a rare opportunity, especially in natural populations, to quantify reproducibility, and therefore the generality of scientific findings. Replicated studies also give us the opportunity to understand ecological differences between populations. For example, a recent study has revealed clear evidence of population-level differences in the plasticity of clutch size in house sparrows.

House sparrows have contributed more to the development of modern biology than we might normally acknowledge. Their close connection with humans has given us greater insights into molecular ecology, conservation, ageing, and even reproducibility in science. Yet, there remains much we do not know about this close neighbour, and still more left for it to tell us.

#### Where can I find out more?

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Evolution & Ecology Research Centre, School of Biological, Earth & Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia.

\*E-mail: [s.nakagawa@unsw.edu.au](mailto:s.nakagawa@unsw.edu.au)

## Correspondence

# Traffic noise drowns out great tit alarm calls

Christopher N. Templeton<sup>1,2,\*</sup>,  
Sue Anne Zollinger<sup>3</sup>,  
and Henrik Brumm<sup>3</sup>

Anthropogenic noise is one of the fastest growing and most ubiquitous types of environmental pollution and can impair acoustic communication in a variety of animals [1]. Recent research has shown that birds can adjust acoustic parameters of their sexual signals (songs) in noisy environments [2,3], yet we know little about other types of vocalizations. Anti-predator signals contain subtle information that is critical for avoiding predation [4,5], and failure to detect these calls [6,7] as a result of anthropogenic noise pollution could have large fitness consequences by negatively impacting survival. We investigated whether traffic noise impacts both the production and perception of avian alarm calls using a combination of lab and field experiments with great tits (*Parus major*), a songbird that frequently inhabits noise-polluted environments. In response to experimental noise manipulation in controlled laboratory conditions, great tits increased the amplitude, but not the frequency parameters, of their mobbing alarm calls (hereafter 'alarm calls'). Playback experiments conducted in the wild indicate that current levels of road traffic noise mask alarm calls, impeding the ability of great tits to perceive these critical signals. These results show that, despite the vocal adjustments used to compensate for anthropogenic noise, great tits are not able to restore the active space of their calls in even moderately noisy environments. Consequently, birds are likely to suffer from increased predation risk under noise, with likely effects on their behaviour, populations, and community dynamics in noise-polluted areas.

When exposed to experimental traffic noise under controlled laboratory conditions, great tits modified the production of alarm calls by increasing call amplitude (the Lombard effect),

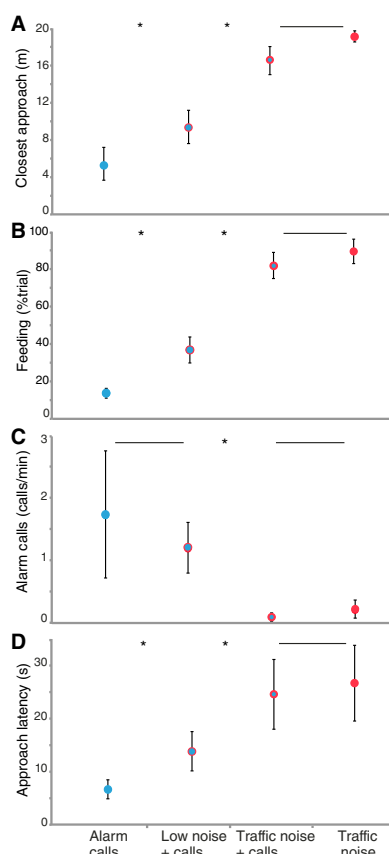
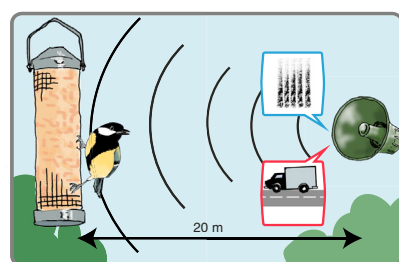
but did not systematically adjust any frequency parameters (see [Figure S1](#) in the Supplemental Information). The Lombard effect — an increase in vocal amplitude in response to increased background noise — had an average amplitude increase of  $7.1 \pm 1.7$  dB between the quiet lab (22 dB) and noisy (70 dB) conditions with traffic noise playback (a mean effect size of 1.5 dB per 10 dB of noise increase, using a generalized linear mixed model, GLMM,  $p < 0.0001$ ; [Figure S1](#)).

We next measured natural alarm call amplitudes of birds living in the wild by presenting them with a taxidermy tawny owl and combined these measurements with recordings of natural road traffic in the same study area. These measurements were used to create audio recordings with realistic amplitudes of both traffic noise and alarm calls (accounting for natural Lombard effect sizes) to use in the perception experiment ([Figure S1](#)).

Last, we played audio recordings of alarm calls to wild great tits and found that traffic noise dramatically reduced their anti-predator responses ([Figure 1](#)). We placed 17 feeders 2–20 m from roads where traffic was frequent but not constant, so that birds would be familiar with traffic noise but we could conduct experiments in the absence of actual cars (for details see Supplemental Information). When birds heard recordings of alarm calls in the absence of traffic noise, they immediately stopped feeding, approached the speaker to investigate the potential predator, and produced their own alarm calls, as expected. However, when the same calls were presented together with traffic noise that mimicked cars driving on adjacent roads 20 m from each bird's territory, tits failed to respond to the alarm calls exhibiting behavior that was indistinguishable from control noise-only playback trials ( $p > 0.45$  for all variables). Adding low amplitude traffic noise, equivalent to a road at 40 m instead of 20 m distance, generally produced responses in between calls-only and noise + calls playback treatments ([Figure 1](#)).

Together, these results indicate that traffic noise impacts both the production and perception of alarm calls in great tits. In noise, great tits modified the amplitude of their alarm calls but none





**Figure 1. Traffic noise impacts perception of great tit mobbing alarm calls.**

Experimental schematic and results from the field playback experiment showing that great tit responses to alarm calls varied depending on presence and level of traffic noise: (A) closest approach to the speaker, (B) percent of trial spent feeding, (C) number of alarm calls produced during the playback, and (D) latency to approach the speaker. The four playback stimuli used were: calls-only, low traffic noise + calls, traffic noise + calls, and traffic noise-only playbacks. Asterisks indicate statistically significant differences ( $p < 0.05$ ) and bars indicate treatments that did not differ.

of the measured frequency parameters, further highlighting the Lombard effect's role in maintaining communication in noise [8]. But although the Lombard effect restores the active space of great tit songs in urban noise [8], our

perception experiments demonstrate that increasing alarm call amplitude is not sufficient to counteract the masking effects of even moderate traffic noise levels for birds living in an otherwise relatively undisturbed environment.

Failure to detect anti-predator signals could have significant negative consequences for animals living near roads and other sources of anthropogenic noise [6,7]. Avian alarm calls provide an early warning signal that is critical for animals to avoid predators. Our data indicate that typical traffic noise 20 m away completely masks tit alarm calls, but noise levels corresponding to 40 m still have significant levels of masking with reduced potential for detection. Even when anthropogenic noise does not completely mask these anti-predator signals, it is possible that much of their more subtle information is lost due to discrimination errors [9]. For example, loss of this public information source, and subtle information about predator type or threat, could lead to incorrect behavioral responses. This unmatched behavior could in turn result in an animal's death, with obvious negative fitness implications.

Noise-related fitness losses may even affect other species: tits and chickadees often serve as sentinel species in avian communities, and other species eavesdrop on their alarm calls to monitor potential predators in their environment [5]. Accurately assessing alarm calls helps animals make effective decisions about how much time to devote to vigilance versus foraging [10], so noise could have negative effects on entire prey communities, ultimately impacting population dynamics. Future long-term work should quantify the population effects of diminished alarm call perception.

While the overall results of this study indicate that traffic noise has dramatic impacts on avian anti-predator communication, the one finding that provides some optimism is that reduced amplitude traffic noise decreases these masking effects. Noise simulating a road 20 m away completely masked the alarm calls but when we increased the simulated distance to 40 m, we observed some release from masking. While responses of receivers were still

reduced compared with control trials, this result still suggests that minimizing amplitude of traffic noise, for example by modifying asphalt composition, tires, or roadside noise buffers, could provide some relief from the masking effects of anthropogenic noise. Striving to reduce noise from traffic, as well as maintaining roadless areas, should be a priority for conservation efforts.

## SUPPLEMENTAL INFORMATION

Supplemental Information includes experimental procedures, one table, and one figure and can be found with this article online at <http://dx.doi.org/10.1016/j.cub.2016.09.058>.

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<sup>1</sup>Pacific University, Forest Grove, OR 97116, USA. <sup>2</sup>University of St Andrews, St Andrews, Fife KY16 9TH, UK. <sup>3</sup>Max Planck Institute for Ornithology, 82319 Seewiesen, Germany.  
\*E-mail: [templeton@pacificu.edu](mailto:templeton@pacificu.edu)